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In-Car Cellular Signal Boosters

White Paper Prepared for:

Wilson Electronics

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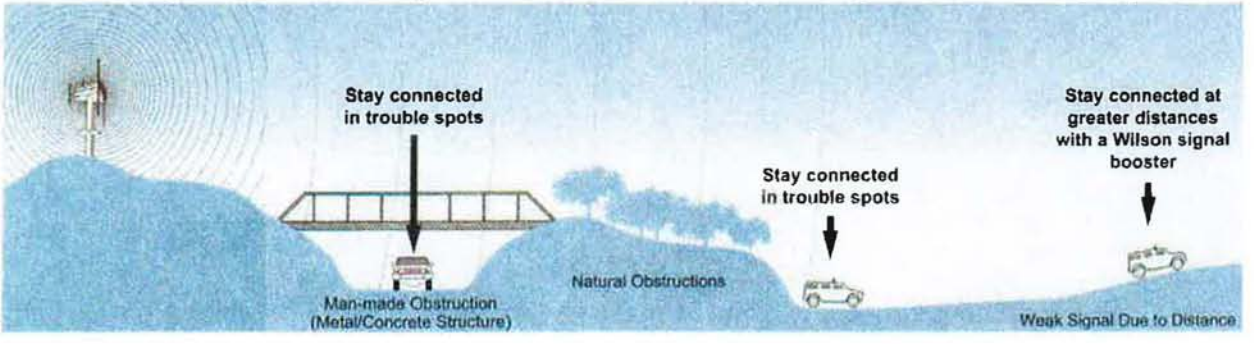
In-Car Cellular Signal Boosters

You're on your phone and you get into your car. Shortly after you close the door you begin the familiar routine, "Can you hear me?" Your call has been dropped. You are in your car on a conference call, using the Bluetooth handsfree equipment built into your car. As you travel to your destination your call is dropped several times, and you must repeatedly dial back-in. Or you may be driving from one location to another and during the drive your phone indicates that you have voice mail waiting but your phone never rang.

The problem is not just dropped calls. If you are using the Internet, you may find it takes longer than expected to access a web page or download an email. Using your phone in a car can significantly lower the speed at which data reaches your phone. And in some cases you can't even access a website or send that important email, because a data connection cannot be established.

Why does this happen?

There are two main reasons for a poor quality signal on your cellular phone. The first is simply distance from the nearest cell site. The farther you are from it, the weaker the signal. This is particularly true in rural areas, where those sites are widely spaced. The second reason is that there may be an obstacle between you and the cell site. Cellular phones communicate using radio waves, and those waves cannot travel through hills or concrete and steel buildings. And even if the signal is not blocked, it is attenuated, or reduced, by metal, glass, and even tree leaves. Thus when you are in an underground parking garage, getting a good signal can be very difficult. Likewise, if your car or office has tinted windows, you will likely have worse reception than if not, for tinted windows typically contain a metal oxide that interferes with radio waves. Further, if your phone is clipped to your belt, inside your purse, or even sitting on the seat next to you, there is even more loss of the signals to and from your phone.



Poor signal strength has another effect on your phone's performance. Wireless networks are designed to minimize the amount of power that your phone uses to communicate with the cell site. The closer you are to a site the less power your phone uses and the longer your battery life. Conversely, the further you are from a cell site, or the more obstacles between your phone and the cell site, the more power the phone must use to communicate, and this will shorten its battery life dramatically. This is why your

car's AM/FM radio has an external antenna: it receives the signal before it is blocked by the metal in your car.

The problems described above are not uncommon. According to market research firm Harris Interactive, 67% of cell phone subscribers have at least occasional trouble with their service, such as dropped calls or no service. Allen Nogee of media research company InStat says that 35% of cell phone subscribers have switched carriers because of coverage issues. And for the 59 million Americans who live in rural areas, poor coverage can be a daily problem.

The Solution

One might think that the solution is for the wireless phone companies to build more cell sites. Unfortunately it is just not practical to guarantee coverage everywhere you might want to use a cellular phone. Wireless Network operators are constantly expanding their networks and adding more cell sites, however this is a lengthy process, taking several years for each new tower to be permitted and built.

Recently network operators and others have started selling devices which are installed in your home or office to provide you with in-building coverage but little has been done to address the issues identified above, providing better transmission and reception within your car or truck. Ten years ago most phone manufacturers offered in-car mounting kits which included an external antenna, as well as a power booster to improve the range of your phone when inside your vehicle. However, when the wireless technologies were updated to digital voice and data, the use of these types of amplifiers could actually interfere with the networks and so were discontinued.

Wilson Electronics has spent years analyzing how digital cellular networks operate. Through this work it has developed a deep understanding of the types of problems which occur when trying to amplify cell phone signals. Wilson has created a unique and smart device which permits you to take advantage of an external antenna and power booster to strengthen the signal to and from your phone. Their booster will seldom cause interference to any of the cellular networks.

Connected to a booster and the external antenna, your phone thinks there is always a cell site close by. Dropped calls are virtually eliminated and data rates are increased. Your phone's battery lasts longer as well, because the phone is no longer transmitting at full power to get its signal to the cell site. The booster's antenna, which is mounted on the outside of your car, receives the network's signal before it is attenuated by the metal and glass.

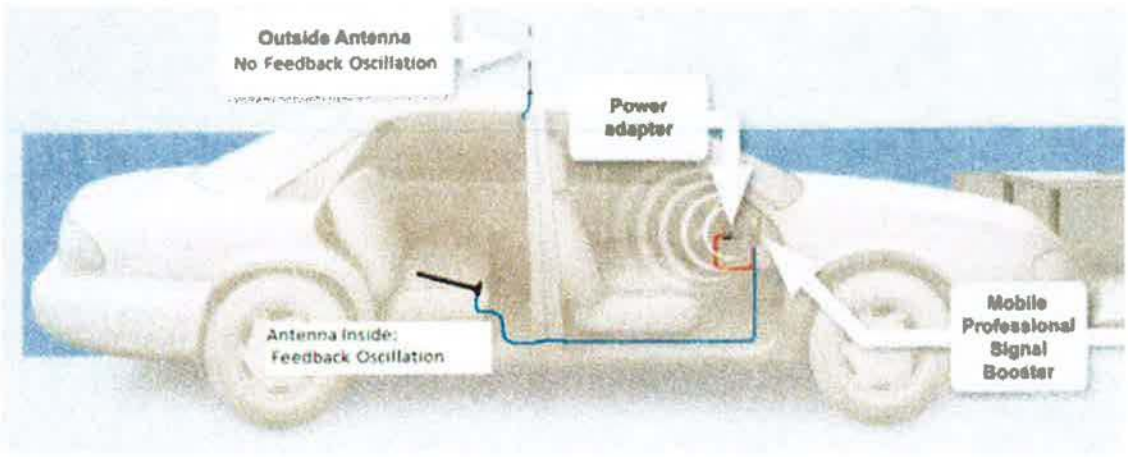
Issues

Designing a booster for a cellular phone is not a simple matter. There are a number of issues which must be overcome or else the booster will cause harm to the network and/or not provide the type of increased reception that is required. Unfortunately there are cell phone boosters currently available in the United States that are not well designed, and which have been shown to cause problems. Currently,

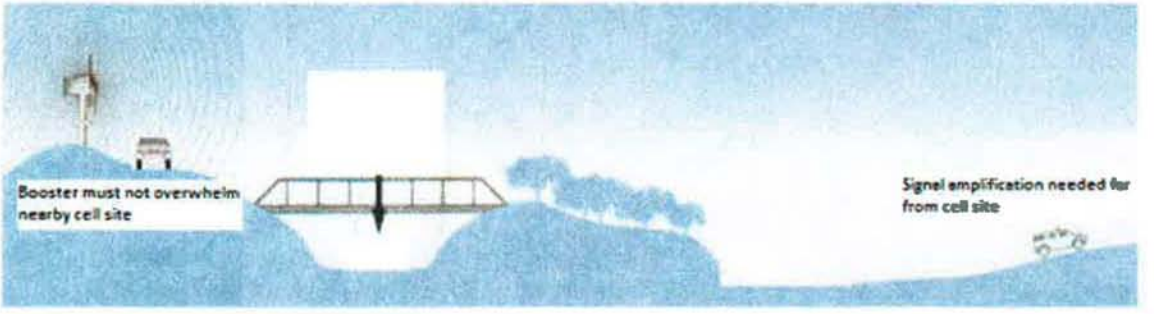
Wilson sets about the complex task of designing and building their boosters guided by two principles: Make sure that the device works as advertised for the customer and do no harm to either the network to which the cell phone is communicating or to any other nearby network. It is important to note that some of the protections currently available were not built into some of its previous, "legacy," products. It is undoubtedly the case that most of the interference wireless carriers have experienced from signal boosters was caused by devices without this adequate protection built-in.

The problems which had to be solved included:

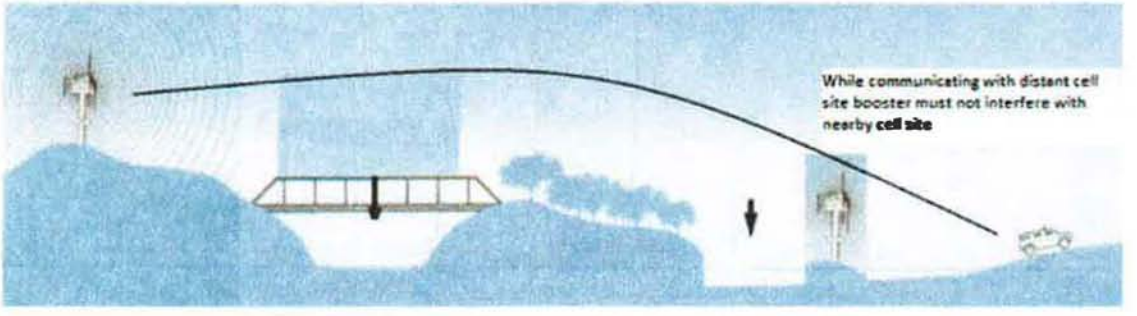
- Avoiding oscillation due to feedback. If the external antenna is placed too close to the in-car cradle (which has its own internal antenna), oscillation due to feedback could occur. You may have experienced similar feedback when a microphone is placed too close to the speaker of a public address system and a howling whine comes out of the speakers. In a cell phone booster, feedback oscillation causes the system to generate noise. This noise signal can interfere with nearby cell sites' ability to receive signals from other cell phones, causing disruption of service to other users, and could actually degrade the performance of the phone inside the vehicle. Thus it is essential to prevent feedback oscillation.



- Preventing overload of the cell site with which the phone is communicating. When you are far from the nearest cell site then the booster needs to transmit at the maximum allowable power. But if you then drive close to the cell site, it must appropriately adjust itself so as not to overwhelm the cell site, disrupting service to other users (And of course if you are close to the cell site then signal amplification is not needed). This prevents any type of network overload or potential interference.



- Avoiding interference to adjacent cell sites. A more subtle variation of the above occurs when your cell phone is communicating with a distant cell site, but there is another cell site (operated by a different carrier) close by. There is a possibility that the booster could cause interference to the other carrier's cell site. If the booster transmits a strong signal in order to reach the distant site, it could potentially interfere with the nearby cell site.



Thus a booster must be designed to avoid transmitting broadband noise that would cause a problem to nearby cell sites.

These issues lead us to two overarching design principles for cellular telephone boosters:

1. Do no harm to the network. The booster must be designed so that under no circumstances will it overload or interfere with any existing wireless network. Network operators are appropriately concerned about the types of devices which can access their networks and the potential those devices to cause interference. There have been situations where devices not properly designed have caused network interference. These incidents affected not only the customers using the equipment but also those who were sharing the same cell site. Also, the booster must not interfere with other nearby networks that may operate on different frequencies or with different network technologies than that of the customer.

2. Be invisible to the network. Beyond not harming the network, a well-designed booster will essentially be invisible to the network. That is, the cellular phone communicating through the booster should always look exactly like a phone that is near the cell site. The purpose of a mobile booster is to increase the range and reliability of a customer's phone in a vehicle. At the same time the booster must be aware of the cellular network, and operate in such a way as to preclude it from overloading or interfering with the network.

To our knowledge, Wilson Electronics is the only company producing cell phone boosters that adhere to these design principles.

Wilson Electronics' Design

The cell phone boosters produced by Wilson Electronics have three key features that address the issues described above.

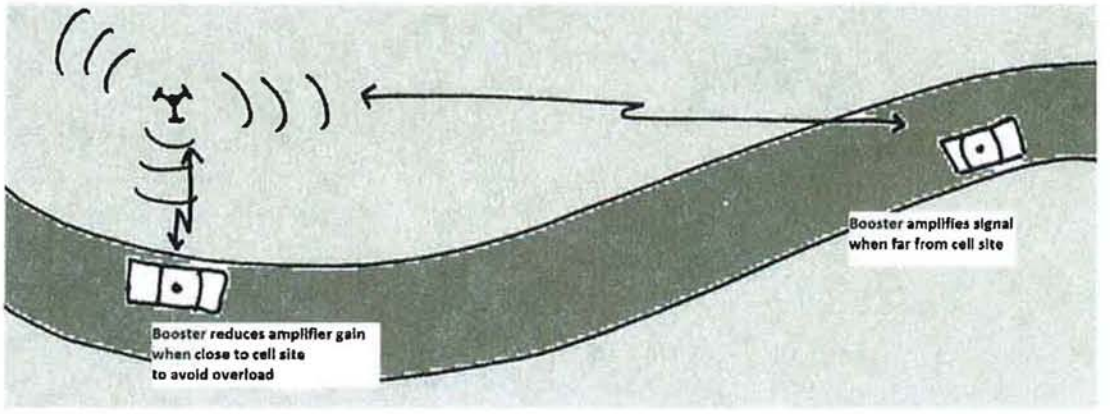
Avoiding Oscillation Due to Feedback

Oscillation protection avoids the problem of feedback. Since in-car boosters are consumer installed, it is possible that the antenna might be placed too close to the internal booster. No matter how-well written the installation instructions, some consumers may install the antenna near the booster. Or even if the initial installation is correct, the antenna might be later moved, perhaps thrown in the back seat when the vehicle is taken through a car wash.

If this happens, the next time the booster is powered on oscillation will occur, which if left unchecked causes the system to broadcast noise, interfering with the cellular network. On the Wilson booster there is an indicator light that turns red when an oscillation has occurred, informing the user that the antenna needs to be repositioned. But more importantly, the booster protects the network by detecting any oscillation. Within 10 milliseconds ($1/100^{th}$ of a second) the booster reduces gain (amplification) or shuts down if needed to prevent network interference. By designing a booster which provides both a visual indication as well as a fail-safe way of preventing oscillation from generating unwanted noise on the network, Wilson eliminates the feedback problem.

Preventing Cell Site Overload

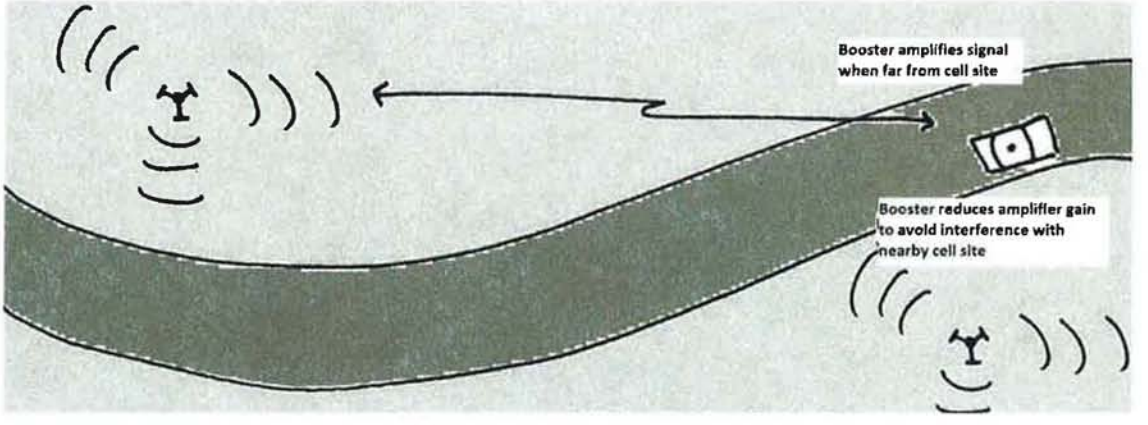
As described above, it is critical to avoid overloading a nearby cell site by broadcasting too strong a signal. When your phone is connected to the cellular network, the cell site constantly communicates with the phone, telling it to adjust the transmit power as it moves closer to or farther from the tower. This happens hundreds of times each second. The Wilson cell phone booster measures both the transmit signal strength from the phone and the incoming signal strength from the cell site. It uses these measurements to determine how close the phone is to the cell site, and adjusts its operation accordingly.



As you approach the cell site, less and less boost of your phone's signal is required. In this situation, the amplifier reduces the gain, or if necessary, shut off completely. Thus at no time is the cell site overloaded with too strong a signal. Then, as you move away from the site and signal amplification is required, the booster comes back on (if it shut down) and continually varies its gain for optimal performance.

Avoiding Interference with Nearby Cell Sites

When any broadband amplifier boosts a signal, depending on its gain, it also can generate detectable background noise. In a case where the cell site with which your phone is communicating is far away, the booster will be amplifying the phone's transmit signal to reach that distant site. If another carrier's site is nearby, it is essential that the booster not generate background noise that could interfere with that nearby site. By continuously monitoring the signal strength of nearby cell sites, the Wilson cell phone booster adjusts the transmitting signal gain (amplification) to avoid the possibility of interference with the nearby cell site, even though that site may use different frequencies or technologies.



As you move away from the nearby tower, the booster can increase signal amplification to give you the best possible connection to your distant cell site.

Other Design Features

Beyond the three key features described above, Wilson cell phone boosters have other design features to protect the cellular networks.

It is important to ensure that the cell phone booster does not interfere with adjacent wireless channels when transmitting. Thus the Wilson transmitting amplifier is designed to have adequate dynamic range. This means that the amplifier is not straining when operating at or near full power. It ensures that the amplifier maintains a linear response to the signal from the cellular phone, and it minimizes the likelihood of the outgoing signal "bleeding" onto adjacent channels.

In addition, the booster must have amplification correctly balanced between the forward link (cell site to cell phone) and the reverse link (cell phone to cell site). Well-balanced amplification is essential to preserve the correct relative power balance in the network. If this is not done, the phone could have problems establishing a call, even though it shows "more bars" from the boosted incoming signal. Some existing products in the market in fact boost only the incoming signal to the cell phone, and do nothing to amplify the outgoing signal from the phone to the cell site. These products can actually worsen communications in areas of marginal coverage.

More than Design

All of this technology is designed to give the customer the maximum benefit of the booster while at the same time ensuring that both the customer's and other networks are fully protected and that the booster will not cause interference to any of the systems. But a great design is worthless if not well manufactured.

Wilson cell phone boosters are manufactured in the United States, in its southwestern Utah facility. Each unit is tested before being shipped. The testing is monitored in real time, and if a problem is discovered, the engineering team is immediately notified. Wilson's advantage in this area is that the engineering team is located adjacent to the manufacturing line, not 6,000 miles away, as is the case for products manufactured abroad. Thus the engineers are immediately available to troubleshoot and correct any problems before the boosters are packaged and shipped.

Experience in Canada

Wilson's experience in Canada with TELUS, one of the largest carriers in the country, is an example of the cooperation that can exist with the carriers. Wilson has sold over 150,000 signal boosting devices in Canada, which TELUS actively markets in the best interest of the citizens of Canada. TELUS cooperated with Wilson on the design and testing of the Wilson 801209 dual-band wireless booster, to insure its use on its system would not cause interference.

In Canada most of the country is rural and cell towers are understandably sparse. Wilson's signal boosters have worked well to provide service where it was not previously possible, or reliable, without any significant system interference. In those circumstances, TELUS cooperated with Wilson in order to

better serve its customers. TELUS' engineers worked closely with Wilson engineers to design and build a product that would not interfere with their CDMA system.

In addition, TELUS developed their own standards for cellular boosters and had Wilson products tested against these standards by independent laboratories. Based on Wilson's experience working with TELUS and going through all of the rigorous testing, Wilson had a similar experience with another of Canada's largest cell phone service providers, Bell Mobility. Bell understands that it is very difficult to cover every part of the country and that Wilson signal boosters can provide an effective tool to helping customers stay connected in weak signal areas. Bell Mobility has approved and marketed multiple Wilson amplifiers over the past several years. The results have been impressive.

A Call for Dialog

Wilson Electronics looks forward to working with the carriers, the CTIA, and the FCC to demonstrate that cell phone boosters are a needed product for many customers, and that they can be safely used without causing interference to the cellular networks.

Existing booster products that do not have the protections described in this white paper are known to cause interference with cellular networks. This is why Wilson believes that the FCC should amend its certification of cell phone boosters to ensure that all cellular networks are protected. All cell phone boosters should be required incorporate the following features:

1. Oscillation (feedback) must be detected and immediately responded to. The booster must either shut down or the amplifier gain reduced to the point where the oscillation feedback is eliminated. This will prevent interference with nearby cell sites.

2. Nearby cell sites must be detected and immediately responded to. The booster must either shut down or the amplifier gain reduced to the point where the output does not exceed established standards. This will prevent the booster's transmissions from overloading the nearby cell site.

3. The booster must support bi-directional signal amplification of the signal from the cell site to the mobile phone, and from the mobile phone to the cell site. Lack of bi-directional amplification can affect the balance of the cellular network.

The FCC certification should document tests that will ensure that any device receiving certification successfully operates as described above. Wilson also believes that the FCC should require that all existing cell phone boosters be re-certified to the new tests within one year of the rule adoption. Wilson is prepared to work with the carriers, the CTIA, and the FCC to develop such tests.

We believe that such a course of action will maximize cellular phone customer satisfaction while ensuring that all cellular networks are free from interference from poorly designed boosters.

Conclusion

Mobile cell phone boosters:

- Are important products that can improve the satisfaction of cellular phone customers.
- Can be designed and built such that they do not harm the cellular networks.
- Should be certified by the FCC, using amended rules to ensure only well-designed boosters achieve that certification.
- Wilson Electronics wants to work with the FCC, CTIA, and carriers to make this happen

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